TRANSPORT MODELLING RESEARCH AGENDA AND NEW DIRECTIONS: EVIDENCE FROM A DEVELOPING COUNTRY

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ABSTRACT

Transport modelling is an essential tool for informed and decisive transport planning, design and policy outcomes. Developing robust, adaptable and intelligent transport models that address daily transport challenges and matters is a pillar and catalyst for enhanced socio-economic growth and development. Noting that models should not only be developed to satisfy scientific and intellectual curiosity it is crucial that models play a pivotal role in reducing science to practice, technology innovation and patents, technology demonstrators, standards and protocols. This is necessary in adding value and ensuring that transport modelling interventions play an instrumental and steering mechanism role aimed at advancing human civilisation on this planet. The chapter conducts a rapid appraisal of transport modelling landscape in South Africa through taking a cross-sectional view of major transport themes and challenges being tackled and gauging the space and location of modelling in these initiatives. Major articles, research papers and policy documents in the public domain are analysed and transport modelling implications discussed. Overall the chapter identifies that not enough transport modelling has been applied in South Africa and there is need to do more in improving the transport modelling dimension of the transport discipline.

Keywords: transport modelling, empirical, development, South Africa.

1 INTRODUCTION

Transportation is an integral component of local, regional, national and the global economy. The growth of economies and populations normally stimulate a commensurate growth in the demand for passenger and freight transport as an example. Meeting the transport needs of growing economies and populations (e.g. energy requirements, infrastructure requirements, agriculture and food security, etc.) requires investment in new infrastructure, maintenance and rehabilitation. A failure to invest prudently in infrastructure can have far-reaching negative impacts on the economy [1]. Central to robust and intelligent responses to growing transportation challenges is the need to employ transport modelling tools and techniques to act as a sponge and hedge against making ill-conceived and ill-informed choices and decisions.

The post millennium development goals (MDGs) – the sustainable development goals for South Africa (a developing country) place sustainable development at the centre of development. Transport growth and development initiatives in seeking to be inclusive will require incorporating climate change, disaster risk, and food security, efficient energy use of resources as top human settlement intervention agenda for both urban and rural areas. Contemporary urban and rural transport developments constitute the heart and soul of a new wave of changes engulfing all spatial areas with differentiated impacts and outcomes. Consequently, in this context concerns are raised about the normative aspects of projects and programmes being rolled out. For example, the loss of natural habitat and biodiversity is a recurring thematic concern for green development activists, agriculturalists as well as rural landscape advocates. At the same time in urban areas, the spiralling and controversial emission of pollutants and release of greenhouse gases into the atmosphere remain a problem. The problems of high motorisation and an auto-mobile dependent society

manifest themselves further in terms of congestion and various chapters of social exclusion. Addressing these matters is necessary as these pervasive challenges cannot be shelved. One way of confronting these matters is through investing in strategic long term modelling to enable scenario development as a way of managing the challenges. Such long term strategic modelling will enable the development of platforms that facilitate better decision making regarding the future infrastructure and land use structuring of both rural and urban settlements. The envisaged modelling footprint will not only be restricted in terms of what can be built, but can also be extended to incorporate the modelling of mitigation measures that can be adopted in seeking to make existing urban and rural systems work better in meeting society's growth and development needs.

It is encouraging to note that transport modelling in South Africa is occurring in a context of growing challenges facing both the first sphere of government and third sphere of government inclusive of local municipalities. Some of the major growth and development challenges in developing countries include the following, namely:

- A growth in the number of poor people living in both cities and rural areas;
- Supply side constraints to economic growth inhibiting capacity of institutions to respond to backlogs, deficits and shortages;
- An inefficient spatial development pattern and form (both urban and rural): The sprawling, low density nature of South Africa's cities imposes significant costs on households, firms and the public sector. This development pattern is evident in all previous Colonial countries within the developing world;
- Rising demand for urban services: Population growth and declining average household sizes place increasing pressure on municipalities, to deliver services; and
- A demanding social/elected citizenry.

Against this background, transport modelling initiatives in developing countries generally and South Africa in particular need to be both sensitive and progressive in tackling complex, dynamic and evolving transport and development challenges.

1.1 Working definition of a transport model

According to the Oxford Dictionary (1976), a (transport) model is "a simplified description of a system, etc. to assist calculations and predictions". Generally, a transport model is considered to be a simple representation of reality [2]. In simple terms, a model represents a simple theoretical abstraction of reality that represent transport systems in such a way that essential features crucial to the development of a transport theory and its application are identified and highlighted [3]. Models can take on different forms, such as maps or mental models. Various 'tools' in the form of computer programmes or software are utilised to produce models [4].

1.2 Purpose of transport models

Among numerous purposes that a transport model serves includes enabling the generation of probable scenarios through the forecasting function. Robust modelling provides evidence based facts and figures to use in deciding on alternatives as an example involving infrastructure investment; determining future transport mobilities and anticipated volumes of traffic on various sections and segments of a network etc. Consequently, modelling play a catalytic and facilitative role in enhancing and supporting the decision-making processes and systems in institutions and organisations. Invariably, transport modelling is a strategic

tool for understanding transport gaps, deficits so as to allow the crafting of strategies and mechanism aimed at optimising existing infrastructure as an example.

Transportation planning, in general, assumes that the future can be predicted from an abstraction of the current realities. Undertaking such a forecasting exercise requires a clear understanding of the vision, mission, strategies, targets and objectives that an institution or organisations seeks to achieve in the future. At the same time, there is need to craft a model which can appraise the effects of different interventions on the performance of the existing or proposed systems. Consequently, transport modelling will not be enough in the absence of an appraisal framework that facilitates comparison of outcomes with operational strategies [5]. Box 1 presents famous quotes on the purpose of (transportation) models which remain critical guiding thinking and framing ideas in contemporary times.

1.3

1.3 Aim of the chapter

The chapter seeks to explore and locate the space of transportation modelling in South Africa specifically and developing countries in general. This is achieved through conducting a rapid appraisal of literature review of documents in the public domain.

1.4 Objectives of the chapter

The chapter seeks to achieve the following, namely:

1. Describe the purpose of transport modelling;
2. Explore the transportation modelling applications and implications in South Africa; and
3. Make recommendations on strengthening transportation modelling in South Africa in particular and the developing countries in general.

1.5 Research methodology

The chapter reviews literature making use of a desktop survey methodology. In addition, interviews with selected key informants and stakeholders were conducted to complement secondary data analysis. The case study adopted is South Africa while the thematic focus area is transport modelling.

Box 1: Classical quotes on the purpose of (transportation) models. (*Source: author's own compilation.*)

If you cannot accurately predict the future then you must flexibly be prepared to deal with various possible futures. Edward de Bono, *Serious Creativity*.

"As simple as possible – but no simpler." Albert Einstein (14 March 1879–18 April 1955).

"The purpose of models is not to fit the data but to sharpen the questions," says Van Vuren. It is attributed to Samuel Karlin (8 Jun. 1924–18 Dec. 2007), an American mathematician. Samuel Karlin Delivered at the Eleventh R.A. Fisher Memorial Lecture, Royal Society (20 April 1983). In Carl C. Gaither and Alma E. Cavazos-Gaither, *Statistically Speaking: A Dictionary of Quotations*, 1996, p. 140.

1.6 Research questions

In order to achieve the chapter's aim of exploring and locating the space of transportation modelling in South Africa specifically and developing countries in general, the following framing questions were framed to operationalise the research aim, namely:

1. What are the main contemporary transportation modelling application areas?
2. What are the main transportation modelling gaps, opportunities and challenges? and
3. What are the major intervention levers for generating the next generation of transportation modelling packages in South Africa in particular and developing countries in general?

2 LITERATURE REVIEW

Numerous integrated land-use transport models exist and are available for use by transportation, land use and engineering professionals. Making a choice on the appropriate land use transport models requires an understanding of an institutions capacity, context and culture. The bottom line relates to employing land use and transport models that maximize the goals and objectives of growth and development. While the generic framework of models is discernible in all models, a detailed review of models highlights significant differences among models. Usually the differences emanate from the following aspects, namely: comprehensiveness; model structure; theoretical origins; modelling techniques; dynamics; data requirements; calibration and validation.

2.1 Forecasting transport impacts and outcomes methods

Overall, forecasting impacts and outcomes of integrated land-use transport policies in rural and urban communities has proved a very difficult task in practice within developing countries. This is because the land use and transport sectors undergo rapid change and are impacted by different concurrent processes and changes at all scales. Despite these challenges, a threefold method of impact and outcome modelling exist, namely:

- Stated preference method: this method relies on asking people about their anticipated reaction to changes such as increased transport costs or land use restrictions for their mobility patterns, activities and behaviour.
- Revealed preference method: this method is based on drawing conclusions from empirically observed behaviour regarding how people travel, why they travel and the impacts of travel behaviour on the environment.
- Mathematical prediction transport models: this method comprises the application of mathematical models to simulate human decision making and its consequences on land use and transport decision framework.

Fig. 1 presents a schematic illustration that highlights that transport intervention impacts change over time, by place and is not evenly distributed within space. Using transport modelling to assist with redressing spatial equity, market distortions correction as well as promoting greater growth and development outcomes is central to interventions. Generally, the value of transport benefits must decline if indirect economic benefits are to grow [6].

Figure 1: Schematic illustration of transport impacts time and spatial distribution. (Source: author's own compilation.)

2.2 Transport modelling development realities and considerations

Transport systems and outcomes can be modelled through employing an endogenous or through adopting an exogenous transport model. Generally, the rural and urban fabric (i.e. including infrastructure networks and land use patterns) undergo slow changes over-time. However, workplaces and housing sub-components have a capacity to change relatively slowly. This is in contrast to the employment and residential population sub-systems that adjust their spatial behaviour fairly quickly to changing circumstances. Freight transport or travel destinations are the most flexible phenomena of urban spatial development. This is because these can be modified almost instantly according to changes in congestion or fluctuations in demand. However, the rural and urban environment is much more complex regarding its temporal behaviour. While it is acknowledged that the land use and transport sector has benefited from a wave of cyclic improvements to modelling innovations over the past, this has not resulted in a modelling challenge free environment. As an example, the transport sub-models used in most current land-use transport models do not fully incorporate and apply state-of-the-art activity-based modelling techniques but the traditional four-step travel demand model sequence which is inadequate for modelling behavioural responses to many currently applied travel demand management policies. Micro-simulation in transport modelling provides the greatest prospect for overcoming challenges associated with the need to reproduce the complex spatial behaviour of individuals on a one-to-one basis. In addition, advances in geographical information systems and remote sensing science have led to increased spatial resolution of models. However, more transport modelling research work regarding neighbourhood (micro level) scale policies and effects is a ripe area for research. More recently Land Use and Transportation interaction (LUTI) models have been extended to deal with regional and inter-regional impacts of transport development [7], [8]. The key weaknesses of LUTI models arise from base model assumptions for example the input-output models are static in nature, dependent on existing patterns of behaviour and can only solve problem through

ensuring that equilibrium is reached in each relevant market. Computable general equilibrium models (CGE models) have at their core the possibility of assuming that consumers display preferences over differentiated goods which are produced by imperfectly competitive firms [8], [9]. Because of this use of a utility function CGE models can make a direct estimate of the welfare effects resulting from a change.

2.3 Mainstream transport models and application domains

Table 1 presents a summary of mainstream urban transport models including strengths and limitations. In short, literature scan reveals the main land use and transportation modelling categories as falling under the following, namely: Land use and Transport (LUT), cellular automata, system dynamics, agent based models (ABMs) and spatial interaction gravity-based models (SE) and Economic Models (EMs). A few of the studies integrated different types of models and there may be some overlaps – for example, LUT and agent based models (ABMs – such as UrbanSim) [4], [10].

Table 1: Urban and rural subsystems represented in land-use transport models. (Source: [11]–[26].)

Models	Very slow		Speed of change				Immediate	
			Slow		Fast			
	Networks	Land-use	Workplaces	Housing	Employment	Population	Goods transport	Travel
BOYCE [Combined models of location and travel choice]	×				×	×		×
CUFM [California Urban Futures Model]	[×	×	×	×	×	×		[×
DELTA [Land-use/economic modelling package]	[×	×	×	×	×	×		[×
ILUTE [Integrated Land Use, Transportation, Environment modelling system]	×	×	×	×	×	×	×	×
IMREL [Integrated Model of Residential and Employment Location]	×	×	×	×	×	×		×
IRPUD [Model of the Dortmund region]	×	×	×	×	×	×		×
ITLUP [Integrated Transportation and Land-Use Package]	×	×			×	×		×
KIM [Non-linear urban equilibrium model]	×				×	×	×	×
LILT [Leeds Integrated Land-Use/Transport model]	×	×	×	×	×	×		×
MEPLAN [Integrated modelling package]	×	×	×	×	×	×	×	×
METROSIM [Microeconomic Land-use and Transport model]	×	×	×	×	×	×		×
MUSSA [‘5-Stage Land-Use Transport Model’]	[×			×	×	×		×
PECAS [Production, Exchange and Consumption Allocation System]	×	×	×	×	×	×	×	×
POLIS [Projective Optimization Land Use Information System]	[×	×			×	×		][×
RURBAN [Random-Utility URBAN model]	[×	×			×	×		[×
STASA [Master-equation based transport and urban/regional model]	×	×	×	×	×	×	×	×
TLUMIP [Transport and Land Use Model Integration Program]	×	×	×	×	×	×	×	×
TRANUS [Transport and Land-use model]	×	×	×	×	×	×	×	×
TRESIS [Transportation and Environment Strategy Impact Simulator]	×	×	×	×	×	×		×
URBANSIM [Microeconomic model of location choice of households and firms]	[×	×	×	×	×	×		[×

Key: [×] Provided by linked transport model.

Overall, in South Africa and within most developing countries the high motorisation and population growth places both rural and urban settlements under different forms of stress and crisis. The need to prepare and plan adequately for rapidly urbanizing and dynamic population shifts and changes in the size, location, density and scale of people, space and institutional implications need clear unpacking. For example, in 2010 Gauteng had a motorisation level of 314 vehicles per thousand people, far above the national average and more than 3.5 times higher than the 85 vehicles/1000 of the least motorised province, Limpopo [27]. Table 2 presents motorisation trends in South Africa.

In many developing countries, South Africa included the considerable infrastructure required for a multi-modal transport system is usually taken for granted as a feature of daily life. Yet at the same time the growth of populations and economies entails that demands on transportation infrastructure and services increase over time and space bringing about new waves of development complexities that require innovative ways of management. This projected and anticipated demand on infrastructure planning and services serves as motivation for the ever increased and improved projections relating to the future demand for transport and the energy required meeting existing and future demand [1], [8], [15].

The next section explores the findings and survey results.

3 DISCUSSION OF RESULTS AND FINDINGS

3.1 Linkage between transport modelling and development in South Africa

Table 3 presents a summary of some of the South African studies examining the links between transport modelling and development. The review reveals that transport modelling opportunities and initiatives exist. These are however hamstrung by being fragmented, ad-hoc, not integrated and therefore lack interoperability. However, these scattered data hungry models represent solid departure points on which strong, robust and authentic transportation modelling platforms and a data meta-language can galvanise from.

Table 2: Motorisation of South Africa's provinces compared to GDP and land area share. (Source: [1].)

Province	Population (2011)	Total self-propelled vehicles (Dec. 2011)	Share of vehicles (%)	Motorisation (veh/1000 persons)	Contribution to national GDP (2010)	Land area share (%)
Eastern Cape	6,829,958	628,529	7%	92	7.7%	13.8%
Free State	2,759,644	478,546	5%	173	5.5%	10.6%
Gauteng	11,328,203	3,560,678	39%	314	33.7%	1.4%
KwaZulu-Natal	10,819,130	1,268,984	14%	117	15.8%	7.7%
Limpopo	5,554,657	474,225	5%	85	7.2%	10.3%
Mpumalanga	3,657,181	585,628	6%	160	7.0%	6.3%
Northern Cape	1,096,731	195,094	2%	178	2.3%	30.5%
North West	3,253,390	457,286	5%	141	6.7%	8.7%
Western Cape	5,287,863	1,485,018	16%	281	14.1%	10.6%
Total	50,586,757	9,133,988	100%	181	100.0%	100.0%

Table 3: Summary of South African studies examining links between transport modelling and development: some insights. (Source: [27]–[29].)

Identity	Geographic scale	Conclusions
Driessen Commission (1974): Report on Committee of the Enquiry into Urban Transport facilities in the Republic	National	<ul style="list-style-type: none"> • Transport alternative; light rail and underground (tube) transport proposals • Pre-feasibility and modelling studies to preclude implementation of such initiatives
Perold A.D. (2000): An Appropriate Strategic Modelling Approach in South Africa	National	<ul style="list-style-type: none"> • Strategic (macro) travel demand modelling needs in South Africa include the following, namely: 1 Interface between travel demand modelling and GIS; 2 Trip chaining (e.g. the ability to not only model a trip from home to work, but also; allow for dropping off kids at school; 3 Time of day modelling (e.g. not just the am peak hour); 4 Presentation of transportation plan results for meetings with officials, politicians, public and other interested parties; 5 Public transport routing and scheduling; 6 User-friendly simulation; 7 Modal integration; and 8 The next generation of travel demand forecast • It is practical to use simulation techniques which are sensitive to people's perceptions and opinions, and the way in which they make trip making decisions
Kane L. and Behrens R. (2002): Transport planning models – an historical and critical review	National	<ul style="list-style-type: none"> • Conventional Large Scale Urban Transport Models – based on a motorization society rather than an urbanizing society (including land-use transport interaction models; disaggregate methods and micro-simulation methods; dynamic methods and activity-based methods, etc.) • Aggregate four-stage models not enough and to be complemented by updating models to local conditions • An expanded approach to transport focuses on individuals instead of vehicles • lives instead of trips incorporating travel substitution, trip inducement, trip suppression etc.
Jennings L (2007): A sustainable transport model for South African cities	National	<ul style="list-style-type: none"> • Network of transport cities sharing ideas and best practice regarding transport modelling initiatives • A viable way of building capacity for generating locally appropriate transport solutions
DoT 2007: Rural Transport Strategy	National	<ul style="list-style-type: none"> • Rural Accessibility Modelling (inferred not explicitly stated) • Rural Accessibility Index since developed
Robinson A (2009): Transport modelling with reference to the Gauteng Freeway Improvement Project	Provincial	<ul style="list-style-type: none"> • The development of the GFIP strategic traffic model was a challenge due to the time constraints. Used previous models as building blocks (i.e. The Gauteng Transport Study of 2000 (GTS 2000), Gauteng provincial model; The Super Highways model, which was a modification of the GTS 2000 developed to test the possibility of tolling provincial roads in the province)
CSIR (2009): Car Ownership study and car use study in South Africa	National	<ul style="list-style-type: none"> • Car ownership policy and decision making model • Car ownership model • Public transport improvement modelling
DoT (2010): National Transportation Master Plan	National	<ul style="list-style-type: none"> • Different transportation scenario requirements • Transport Modelling by mode, scale and over time

Table 3: Continued.

Identity	Geographic scale	Conclusions
Wray C., Musango J. and Damon K. Gauteng City-Region Observatory (2013): Modelling urban spatial change: A review of international and South African modelling initiatives	National	<ul style="list-style-type: none"> • LUT models currently incorporate transportation modelling processes of trip generation, distribution, modal split and assignment explicitly and are consistent with discrete choice methods based on utility maximising, specifically in their simulation of trip-making • More recently, a new generation of micro-simulation models that attempt to account for the behaviour and interactions of individual agents in space and time have been developed • A few examples of newer LUT models include: UrbanSim (Waddell, 2002), Integrated Land Use Transportation Environment (ILUTE) (Salvani and Miller, 2005) and Integrated Land-Use Modelling and Transport System Simulation (ILUMASS)

3.2 Transport modelling projects in South Africa: some examples

A number of transport modelling projects exists in South Africa. These are found at different spheres of government as well as cut across research institutions and Universities. Despite the fact that the majority of the systems are developed as stand-alone projects and are not integrated they however constitute a good point of departure for developing future integrated transport modelling platforms in South Africa. Table 4 presents some of the specific examples of transport modelling projects in South Africa.

3.3 Transport modelling initiatives: the case of the Department of Transport

The Department of Transport is the government department which in terms of its mandate provides leadership in the promotion of sustainable transport development among other important objectives. One of the areas of leadership is transport leadership through modelling interventions to assist decision makers regarding different transport future pathways and options. Table 5 presents examples and opportunities for transport planning as informed by the Department of Transport Strategic Plan.

Table 6 presents the DoT's detailed performance in 2012/13 per programme, including some selected highlights and implications for transport modelling in South Africa.

Table 7 presents transport modelling research gaps and opportunities in South Africa as informed by this research and analysis.

Table 8 presents some existing transport modelling governance in South Africa. Developing robust transport governance frameworks and systems is central to moving ahead the transport modelling agenda in any area or region.

3.4 Key transport initiatives and modelling implications in Gauteng province, South Africa

While some of the transportation applications areas in South Africa have been identified in Tables 4–8, Table 9 presents the gaps, opportunities and challenges related to transport modelling in South Africa. In summary, Table 9 presents that the problem in South Africa is not that there is no transport modelling. It indeed exists but as pockets of scattered transport modelling initiatives that do not have high impact. There is need to upscale the transport modelling applications by scale as well as intensity. Making use of Table 2, the intention of transport initiatives in Gauteng province is to deliver an enhanced road and

Table 4: Examples of specific transport modelling projects in South Africa. (Source: [27]–[29].)

Identity	Description	Application	Issues
Quantifying the energy needs of the transport sector for South Africa: A bottom-up model. This was developed by the Energy Research Centre in 2012	The project focused on the development of a number of models which, when combined, can be used to develop scenarios to answer questions around the likely future energy and infrastructure requirements of the transport sector and its major influences in terms of both energy and emissions.	Passenger transport Freight transportation	<ul style="list-style-type: none"> Data with which to populate transport sector models is sparse in South Africa and hence a broad range of input assumptions had to be made to facilitate finalization of the model. Transport energy demand under business as usual will double by 2050. The vehicle fleet will have grown to exceed 24 million road vehicles by 2050 from a baseline of 8.2 million in 2010. Of these, over 17 million will be private vehicles, excluding light commercial vehicles. It is possible to constrain the increase in energy demand to less than 30% with a trend towards stabilisation through policy instruments. Modelling of intracity and intercity travel within and between provinces would allow the calculation of future transport fuel use for each province, which will aid decision-making around infrastructure investment and opportunities for alternative transport modes. Finally, collaboration between researchers in South Africa working in the transport sector would greatly enhance both base year data and transport sector modelling.
Reducing greenhouse gas emissions and facilitating the transition to a green economy. This was developed in 2013 by the National Treasury.	The National Treasury's modelling is based on a dynamic computable general equilibrium (CGE) model that seeks to capture the complex economic relationships between producers and consumers, and between domestic and foreign economies. The study models the impacts of a carbon tax imposed upstream on fossil fuel inputs (coal, crude oil and natural gas) and implemented gradually over a period of 10 years. The impacts of the carbon tax on key variables are considered over a period of 25 years, including the level of emissions reductions, overall output, employment, investment, competitiveness of different sectors, and different income groups.	Emission reductions for the transport sector Energy-efficient modes of freight and public (passenger) transport Use of alternative, cleaner fuels Safe and affordable public transportation A shift of freight from road to rail	<ul style="list-style-type: none"> Emission reductions for the transport sector can be achieved by improving the availability of more energy-efficient modes of freight and public (passenger) transport, and promoting the use of alternative, cleaner fuels. Low-income households spend a large proportion of their incomes. Study indicate that the transition to a low-carbon, climate-resilient economy will depend on the current structure of the economy; the incentives for technical and behavioural changes, the way in which revenue is recycled, and the extent to which energy, transport, industrial and trade policies are coordinated with environmental policy. The model suggests that a carbon tax, coupled with various revenue recycling options, will have a limited negative impact on economic growth and will assist in nudging the economy onto a more sustainable and low-carbon growth path. Evidence suggests that tax shifting (which involves taxing "bads", such as pollution and GHG emissions, and reducing taxes on "goods", such as payroll and income) could generate both environmental and employment benefits. The most positive impacts for the recycling of revenue emanate from the channelling of funds towards new productive investments in the respective sectors. There may be scope for further investment in low-carbon technologies by both the government and the private sector.

Table 4: Continued.

Identity	Description	Application	Issues
The creation and application of a national freight flow model for South Africa. This was developed in 2012 by J.H. Havenga and W.J. Pienaar	The NFFM focuses on defining surface freight transport (i.e. road and rail) based on the two definitive measures of flows, namely tons and ton-kilometres. The model is a descriptive model fitted on historic data.	Freight transport logistics	<ul style="list-style-type: none"> • South Africa suffered from a historical lack of freight-flow information that was detrimental to infrastructure planning, optimal network development and market structuring. • Due to the nature of the input information for road data, the model produces aggregate tonimages as well as corridor flow estimates, but not at the level of detailed origin-destination flows. • Subsequent to the development of the NFFM, a detailed origin-destination model was, however, developed for South Africa, based on the input-output model, with a 30-year forecast (Havenga et al. 2011). • The relative ease of updating of the NFFM (compared to the onerous input-output model) allows the two models to act as invaluable mutual validation tools, and the validity of both models have been established and is being tracked over time (CSIR, Imperial Logistics and University of Stellenbosch 2010).
UrbanSim. This was developed by the CSIR		Urbanisation modelling Fragmentation modelling Integration modelling Land-use and transport modelling	<ul style="list-style-type: none"> • The highly technical, data hungry and complex UrbanSim model represents the top-end of urban simulation. • The planned operationalisation of the Gauteng-wide GIS platform, or GeoGCR spatial database by the Gauteng Planning Commission (GPC), and establishment of a national observatory, proposed by the National Planning Commission (NPC), represents an opportunity for integrated modelling coordination and sharing of outputs across different spheres – local, regional and national (i.e. creation of an integrated modelling platform). • Careful consideration should be given to the possible overlapping roles and work of the national observatory and stepSA (Spatial Temporal Evidence for Planning South Africa) programme.

public transportation service that meet current and future transport requirements for the region. Table 9 presents a summary of the key transport initiatives in Gauteng Province including the transport modelling implications. The forecasted sum of implementing these transport modelling inspired initiatives is that the Gauteng Province in South Africa will move from a phase “of transport access and constraints gridlock loop” to one of “transport access and constraints opportunities motion and continuum”.

Table 5: An example from DoT’s Integrated Transport Planning programme objectives: implications for transport modelling. (Source: [27]–[29].)

Programme objective	Implications for transport modelling
Facilitate multi-modal transport planning on an ongoing basis by:	Multi-modal transport modelling
Developing an enabling consolidated transport planning databank by 2015.	Using the consolidated transport planning databank for scenario (projection) planning
Developing the Multi-modal Integrated Transport Planning draft Bill by 2015.	Multi-modal integrated transport planning modelling
Assist line function operations with socioeconomic analysis of the transport sector by providing economic modelling and transport data on an ongoing basis.	Transport modelling of commuter and travel patterns in Urban areas
Reduce cross border system costs as well as transit and turnaround times to enhance trade within the Southern African Development Community region and Africa as a whole by:	Cross-border logistics modelling
Propose innovative and applicable technologies for improved and environmentally sustainable transport systems through research, innovation, monitoring and evaluation on an ongoing basis.	Low carbon economy transport scenario modelling at all scales and by sectors
Ensure evidence based transport planning and policy making by conducting a household travel survey and publishing its result by the end of 2013/14 to support public transport and infrastructure investments.	Household Travel Survey Modelling

Table 6: DoT’s detailed performance in 2012/13 per programme: some selected highlights and implications for transport modelling in South Africa. (Source: [27]–[29].)

Programme 02: Integrated Transport Planning (ITP): sub programme: research and innovation			
Key performance indicator	Target	Achieved / not achieved	Transport modelling implications
Develop a sustainable transport information portal, accessible at all tiers of government	A sustainable transport information portal	Achieved	Raw source data and information sets that can feed into various transport modelling initiatives
Develop a rural accessibility/multi-deprivation index	Accessibility index conducted for 12 rural districts: Alfred Nzo, Amajuba, Amatole, Chris Hani, Joe Gqabi, O.R. Tambo, uGu, uMgungundlovu, uMkhanyakude, uMzinyathi, uThukela, and Zululand	Achieved	Opportunity to engage in detailed rural transport accessibility modelling in these 12 rural districts
Research on the impact of freight accidents on South	Discussion document on the impact of freight accidents on South Africa’s roads	Not achieved	Freight accidents modelling
Develop rural-specific indicators and targets to monitor freight performance within IDPs and ITPs	Roll out and coordinate to other rural provinces	Achieved	District and local level freight transport modelling
Identify and develop strategic rural freight logistics infrastructure	Roll out and coordinate to other rural provinces	Achieved	Freights logistics hub modelling

Table 7: Low-hanging existing transport modelling fruits: research agenda and gaps. (Source: [27]–[29].)

Current research area	Research gaps	Proposed research direction and new research focus area
BRT Rea Vaya	Integrated Ticketing System Expansion of BRT route system beyond core network	All 13 Cities where IRPTN is being implemented including Rustenburg
Gautrain rapid rail Link	Alternatives such as LRS Expansion of the RRL Feasibility of underground rail systems (tube transport)	Gauteng Region
IRTP (Integrated Rural Public Transport Planning)	Rural transport test case/pilot	At least 2 Rural District Municipalities in NW Province including all Pilot Rural Integrated Public Transport Pilot cases
Compact city models – development	Exploring on ToD; catalytic and flagships projects to fast track the transition	All least for a start all provincial and major towns in South Africa

Table 8: Some transport modelling governance initiatives in South Africa. (Source: [27]–[29].)

Governance initiative	Justification	Transport modelling scope
Gauteng Integrated Transport Modelling Centre (GITMC)	A response to the shortcomings of ad-hoc and fragmented transport modelling outcomes of commissioned research projects.	The CSIR, in conjunction with the UP was appointed to set up the GITMC as a multi-year project. The project is aimed at enhanced co-ordination and integration of transport modelling needs for governments within Gauteng by pooling resources and expertise.
Gauteng Integrated Transport Master	Generation of transport modelling scenarios for GITMP i.e. for 2010 base year and design years 2015, 2025 and 2037).	A total of 833 traffic zones covering Gauteng and surrounding areas have been modelled over a period of seven months. At the time of writing this chapter, there was no structured collaboration between the GITMC and ITMP25 modelling initiatives, highlighting the lack of collaboration and possible duplication of modelling efforts.
eThekweni's Accessibility Model	eThekweni uses the spatially explicit Accessibility Model to understand the future social services requirements of its housing planning projects. Based on population numbers, incomes, and age profiles, the model simulates the supply of and demand for social facilities across the municipal area. It also takes into account the existing backlog in facilities.	The Accessibility Model uses GIS and modelling to generate quantitative information. So far it has reinforced the need to cluster public investment in nodes and along corridors as well as aid decision making in housing planning exercises. Being a micro-model, it has signified a move beyond broad and conceptual spatial planning through the formulation and use of standards. Given that the model has proved to be very useful in matching the supply of and demand for social facilities, it has helped to avoid unnecessary and wasteful development in this regard.

Table 9: Sample of key transport initiatives and modelling implications in Gauteng Province. (Source: [27]–[29].)

Key transport initiative	Implementation levers	Expected outputs	Transport modelling implications
Transport Authority for Gauteng	Institutional	<ul style="list-style-type: none"> • Agreement on an appropriate institutional structure • Business plan and funding arrangements • Institutional development and strengthening 	<ul style="list-style-type: none"> • Transport governance and modelling
Effective Management of Existing Transport Infrastructure	Institutional	<ul style="list-style-type: none"> • Gauteng Integrated Investment Road and Transport Infrastructure Plan • Utilisation and updating of The Gauteng Pavement Management System (GPMS) for road maintenance, rehabilitation and construction • Capacity building and training to establish a critical mass of experts 	<ul style="list-style-type: none"> • Infrastructure Rehabilitation Modelling • Infrastructure maintenance Modelling • New Infrastructure Construction Modelling
Regulation and enforcement	Institutional	<ul style="list-style-type: none"> • Strengthening municipal traffic departments • Road Safety Action Plan • Improved over-load control and enforcement • Traffic Route Integrity Audits • CCTV along major activity corridors 	<ul style="list-style-type: none"> • Traffic accidents modelling • Transport disaster risk modelling
Provincial-wide public transport information centre	Intelligent traffic (transport) information systems	<ul style="list-style-type: none"> • Common GIS, data structure and databases platforms • Link to advanced public transport management systems (APTMS), Fleet management, GPS and vehicle tracking • Scoping of platform(s), setting up call centre and supporting back office 	<ul style="list-style-type: none"> • Single transportation planning modelling platform
“One Province One Ticket”	Transport integration	<ul style="list-style-type: none"> • Implementation of the Integrated Fare Management (IFM) framework and strategy • Operational integration of public transport services • Common data structures, databases and warehousing 	<ul style="list-style-type: none"> • Integrated ticketing modelling • Price/fare costing modelling • Transport operations/costing modelling
Integration with the Commuter Rail Corridor Modernisation Project of PRASA	Transport integration	<ul style="list-style-type: none"> • Inclusive joint planning which does not exclude any stakeholder • Agreement on priority focus stations (i.e. Germiston, Vereeniging, Roodepoort and Leralla) • Operational integration with other modes • Non-motorised transport facilities and directional signage 	<ul style="list-style-type: none"> • Rail freight modelling • Rail passenger modelling

Table 9: Continued.

Key transport initiative	Implementation levers	Expected outputs	Transport modelling implications
Transformation of taxi industry	Institutional	<ul style="list-style-type: none"> • Taxi industry re-organisation and corporatization strategy • Streamlined registration and licensing system • Business opportunities on IPTN with associated financial support • Pilot project 	<ul style="list-style-type: none"> • Taxi corporatization modelling • Taxi operational financial modelling • Taxi route operations modelling
Access to major freight nodes	Institutional	<ul style="list-style-type: none"> • Integration with PRASA Passenger Rail Plan • Finalization of Integrated Public Transport Network Plan • Upgrade and development of key road links and section • Dedicated freight routes on the periphery of urban area (for freight to flow directly to and from the N1/N12 via the freight terminals to Limpopo, Mpumalanga and KwaZulu-Natal (KZN)) 	<ul style="list-style-type: none"> • Road freight modelling • Maritime transport modelling • Air freight (aviation) modelling • Freight logistics border delays modelling • Inland dry ports modelling
Restructured subsidized road-based public transport	Transport funding	<ul style="list-style-type: none"> • Appropriate modes to be deployed on the IPTN corridors and links (i.e. BRT, express bus, bus and mini-bus) • Integration of funding strategies • Establishment of a common basis for contracting public transport operations 	<ul style="list-style-type: none"> • Subsidy and scenario modelling • IPTN modelling • Integrated rural public transport networking modelling (pilots)
Green public transport vehicle technologies	Transport sustainability	<ul style="list-style-type: none"> • Green re-fleeting strategy • Co-ordinated and planned demonstration projects including bio-fuel development and processing facilities; substantial distillery ethanol manufacture plant and; conversion of public transport vehicles 	<ul style="list-style-type: none"> • Low carbon economy modelling and scenario building
Travel demand management, less congestion and shorter travel times	Land use and transport planning integration	<ul style="list-style-type: none"> • Creation of capacity to manage TDM and transport systems management programmes • Set new standards transportation infrastructure and services • Effective management of transport infrastructure • Optimisation through deployment of ITS and TDM measures • Restructuring of land use and development patterns 	<ul style="list-style-type: none"> • Land use modelling • Transport demand modelling • Transport supply modelling

Table 9: Continued.

Key transport initiative	Implementation levers	Expected outputs	Transport modelling implications
International and city airports	Institutional and transport integration	<ul style="list-style-type: none"> • Coordination between all role-players and integration of planning • Assess impacts on land and associated development • Transport accessibility and linkages • Early anticipation and prevention of bottlenecks developing in relation to air passenger and freight movements 	<ul style="list-style-type: none"> • Aerotropolis modelling
Pedestrian paths and cycle ways	Transport integration	<ul style="list-style-type: none"> • Provision of NMT infrastructure and facilities (with “urban” greening) associated with key PT nodes and Provincial roads • Finalisation of the Provincial NMT policy and strategy • 50 km pedestrian paths 	<ul style="list-style-type: none"> • Cycling bus modelling • Walking bus modelling • NMT modelling
Continued provincial-wide mobility	Transport integration	<ul style="list-style-type: none"> • Utilising Gauteng Freeway network as the “backbone mobility road network” of the province, implement NATMAP strategic projects for Gauteng, namely: <ul style="list-style-type: none"> • Strategy 1: Develop a link between Johannesburg and Rustenburg via Lanseria Airport and the N4 Platinum Corridor; • Strategy 2: Provide a link between Sandton and the N4 Platinum Corridor; and • Strategy 3: Link the N3 to the N4 Maputo Corridor through Ekurhuleni, specifically catering for freight haulage 	<ul style="list-style-type: none"> • Public transport modelling (bus, taxi, rail etc.) • Transport corridor modelling • Transport regional development modelling
Accessible transport	Transport integration	<ul style="list-style-type: none"> • Providing accessible transport for people with disabilities, persons with disabilities to have equal access to transport facilities and services available to the general public; to the greatest extent possible, in rural and urban areas • Continued improvement and development of IRPT systems namely: <ul style="list-style-type: none"> • BRT Rea Vaya • BRT Are Yeng • Ekurhuleni IRPTN (Aerobus?) • Gautrain rapid rail link expansion • Metro rail modernisation and expansion • Gauteng Freeway Improvement Plan and e-tolling 	<ul style="list-style-type: none"> • Accessibility modelling • Multi-modal modelling • Inter-city movements modelling • Intra-city movements modelling

Table 2 overall resonates in the lack or existence of inadequate integrated transport modelling systems in Gauteng province in particular and developing countries transport sectors in general. It is therefore little surprise that the Gauteng Department of Roads and Transport (GDRT) has identified the need for integrated land use and transportation planning and integrated planning tools to inform robust decision-making. A recent report on modelling urban spatial change highlighted the fragmented approach to transport modelling within Gauteng [4]. Traditionally, GDRT has commissioned provincial transport modelling from transport consultants. There has also been a varied response to transport modelling at a local government level with a combination of outsourced and internal models and a range of proprietary software. The result has been a disjointed approach, limited modelling capacity and skills development within government, and a mismatch of macro and micro-scale modelling [28], [29]. In 2012, terms of reference were issued by GDRT for the establishment of the Gauteng Integrated Transport Modelling Centre (GITMC). Its aim is to create a fully operational modelling centre, co-owned, co-funded and co-staffed by a range of provincial and municipal departments. It will provide high-end planning and modelling skills for a variety of macro and micro-modelling support services to role-players across the province [1], [8], [16], [28], [29]. The Council for Scientific and Industrial Research (CSIR), in conjunction with the University of Pretoria, have been appointed to set up the GITMC as a multi-year project. The centre will initially build on the data and models generated by the CSIR UrbanSim and MATSim software urban simulation project. It will formulate urban growth scenarios at a local and provincial level taking into account current and planned transport infrastructure initiatives. The centre is planned to be fully operational by 2014 [2], [28], [29].

4 LESSON LEARNED RELATED TO RSA AND APPROACHES IN DEVELOPING COUNTRIES

The main constraints and challenges that are related to upscaling transport modelling relate to the need to address various delivery and performance bottlenecks that lead to ineffective and inadequate transport solutions. These can be summarized precisely as follows, namely:

- Adequate financial provisioning to meet research and development (R&D) transport modelling projects and interventions requirements: Financial resources remain one of the main constraints in Metropolitan and District Municipalities to fulfil their obligations in terms of transport interventions. The problem can be appreciated better if one notes that in South Africa investment in road infrastructure has on average decreased by 1% annually since 1975 [30]. Financial constraints surrounding the maintenance and operation of ambient monitoring stations; conducting oversight studies as well as implementing a package of integrated transport planning and spatial turn measures is hamstrung by lack limited resources. Financial resources are essential to ensure the successful implementation and enforcement of sustainable transport agenda.
- Limited resources of transport and spatial planning modelling experts: A solid base of critical and adequately skilled transport and spatial modelling experts that can provide sustainable and decisive leadership to turn-around transport measures and actions through projects that transform the transportation landscape. While currently the metros make use of consultants to fill the gap the problem is that the inputs are ad-hoc and difficult to integrate. For example modelling systems and bases used by different consultants are usually not compatible. Building the next generation of

transport and spatial experts to take the urban and rural regions into smart future regions requires investment in manpower development and training.

- Dynamic transport authority and progressive transportation leadership: Inter-governmental and inter-departmental communication and cooperation are major constraints in ensuring successful transport measures and actions. Without the mutual understanding between related departments such as land-use planning, road infrastructure development, urban zoning and air quality management, transport and land use commuting orientated intervention and strategies are setup to fail at the implementation phase. This also applies to the inter-governmental linkages between municipal and provincial government where synergy is essential. A holistic approach which goes over the constraints of the “silo based approaches” despite the existence of the municipal inter – structures coordinating act (i.e. in South Africa for example and similar legislation in developing countries) is therefore needed in the transport and spatial related growth and development management strategies.

Consequent to this chapter’s findings, Fig. 2 presents future transport modelling thematic areas in South Africa: some prospecting thoughts. Fig. 2 shows that a five-point transport modelling research agenda is required to tackle transport modelling challenges in South Africa. A similar strategy can also be developed in other developing countries but modified and informed by the transportation growth and development context of the specific country. These five critical intervention areas are namely: travel demand and behaviour; delivery of transportation services; transportation finance; sustainable development and advanced transportation system operations and performance. If sustainable and high impact outcomes are to be realised in the transportation sector equal and simultaneous investment in all the five identified areas is critical.

Table 10 presents an elaborated version of the possible research focus areas for transport modelling in South Africa and developing countries including a clear description of the problem statement and potential projects and themes for investigation.

Figure 2: Future transport modelling thematic areas in South Africa: some prospecting thoughts. (Source: author’s own compilation.)

Table 10: Travel demand and behaviours research focus area. (Source: [27]–[29].)

Research focus area	Problem statement	Recommended potential projects/topics
Understanding fundamental ways in which travel behaviours and patterns may change in the future, and what these changes may mean in terms of transportation system needs and requirements.	<p>Examine the long-term interplay between changing demographics, lifestyle choices, affluence/wealth, and settlement patterns on personal transportation demand.</p> <p>Develop improved tools for scenario analysis and forecasting that account for these considerations.</p>	<p>Dynamic and future travel behaviour and patterns mobilities research focus area</p> <p>Analyse shifting patterns of population growth and personal income and its effect on transportation demand/needs.</p> <p>Examine a sample of existing long-range transportation and land use plans from metropolitan areas to assess and model to what extent they account for potential changes in development patterns and travel demands in response to changing demographics, technology, climate change, and other factors.</p> <p>Develop improved travel demand forecasting models or approaches to modelling, which account for the potential influence of long-range changes in factors affecting travel demand; this may include a structure for developing regional scenarios, accounting for risks and uncertainties regarding technologies and other factors.</p>
Addressing the potential of new technologies and approaches to create a more efficient and effectively performing transportation system.	<p>Study the range of multi/inter-modal connectivity options, focusing on how to optimize different forms of system capacity, improve reliability, and create a seamless transportation system.</p>	<p>Advanced transportation system operations and performance research focus area</p> <p>Conduct a transport modelling fore-sighting study that clearly defines the likely technological characteristics of desired future multi-modal transportation systems in order to provide a framework for areas where technological improvements could be developed by a non-transportation entity. Explore the generation of an adaptive modelling system involving all players in transportation (pedestrians, business, shippers, system operations, police, etc.) in order to facilitate intelligent and adequate designs for future systems.</p>
Exploring the potential for new approaches to developing and preserving transportation infrastructure in light of potential changes in resource availability and cost.	<p>Examine new approaches and technologies to enhance system preservation, maintenance, and renewal in light of expectations about decreasing supplies of natural resources, increased global competition for resources, and a focus on environmental sustainability.</p>	<p>Sustainable transportation research focus area</p> <p>Explore the potential consequences – intended and unintended – of developing new fuel/energy sources for transportation. This may include changes in international trade and fuel shipments (e.g., shipment of hydrogen), development of new South African-based or foreign technologies and associated impacts on the economy (e.g., new manufacturing, shipment, and energy distribution facilities), and impacts on agriculture (e.g. food production to fuel production) and other sectors of the economy.</p> <p>Develop a model to forecast carbon footprint and analyse potential benefits of alternative freight systems, considering modal alternative, freight bottlenecks, modal connectors, reduction in truck idling, truck – only lanes and fair pricing, rail, and water.</p>

Table 10: Continued.

<i>Research focus area</i>	<i>Problem statement</i>	<i>Recommended potential projects/topics</i>
Transportation finance research focus area		
Addressing immediate funding and financing issues to address broader, longer-term approaches, which may rely on new technologies and institutional approaches.	Investigate and explore potential new financing mechanisms and approaches, considering new technologies, privatization, and institutional approaches.	Consider the future of government finance and the likelihood of privatization for parts of the transportation sector. Research legal and funding options to foster and allow for lower cost implementation of transportation projects while upholding environmental standards and requirements. Assess the ability of multi and intermodal approaches ability to minimize the effects of reduced funding.
Delivery of transportation services research focus area		
Assessing the capability to deliver transportation projects, operate services, and preserve system infrastructure effectively is essential to transport authority' success.	The knowledge economy/society plus technological changes are dramatically altering public interaction in general, with public transport authorities, and regarding transportation projects and other public goods.	Investigate the need for new public communication and involvement techniques, factoring in/capitalizing on current and anticipated social changes. Identify future increased expectations for greater transportation information from younger, more technologically sophisticated people. Assess and model future organizational structures and capacities to manage the scale of impacts and benefits of transportation. Research policy architectures to enable effective decision-making at various levels of government and across a broad spectrum of functions (e.g., transportation, environment, land-use). Identify how regulations will be categorized: life cycle costing, performance-based, or outcome-based. Identify the long-term transportation work-force composition, retention, and preparation. Consider changes in retirement patterns – specifically that people are choosing to work further into their life. Analyse role of academia in providing for the transportation workforce's future needs, both with degree programs and continuing education.

5 CONCLUSIONS

This chapter has identified that not enough transport modelling has been applied in the South Africa. The same conclusion applies to other developing countries. Scope and room for improved transport modelling in the transport discipline exist. It is also interesting to note that transport modelling main applications areas has been metropolitan and urban areas with lack of equal emphasis in small and medium sized rural towns. This gap is mirrored too in terms of greater scale of modelling initiatives in urban transport planning compared to rural transport. Looking into the future, the need to balance transport modelling applications in urban and rural areas is central to facilitating enhanced transport improvement outcomes aimed at increased balanced development, tackling regional economic disparities and inequalities as well as promoting sustainable inclusive development goals and outcomes. However, in the final analysis transport modelling alone should and cannot be expected to be the one and only ultimate answer to urban and rural transport growth and development challenges. Transport modelling interventions need to be complemented by appropriate transport policy and a legislative framework. This should be directed in the context of the correct set of transport planning, engineering and management adaptive governance systems. While getting the “transport wheels sector oiled and moving” is central to transport contribution to the economy, it is essential that similar and appropriate interventions in the other growth sectors of the economy such as health, education, mining, agriculture and manufacturing industry to name a few is correctly positioned and aligned to promote shared growth and development outcomes of a country. While encouraging growth and development in economies is always challenging, it is acknowledged that the establishment of intelligent transport and non-transport modelling platforms constitutes a critical and vital cog of development that should not be missed or easily forgotten.

In the context of South Africa in particular and developing countries, there is still a considerable need for further transport modelling work i.e. covering the full transport gamut including urban and rural road, rail, air, inland water and maritime sectors. The need to balance macro, meso with detailed and focused micro transport modelling studies and projects tailored to respond to specific changes in order to have in-depth understanding of the process of decision making in response to changed transport provision by both individuals and households, and firms is fundamental. The general observation that transport modelling tool and technique been under-utilised in South Africa and developing countries in general has resonates in the need to revamp and restructure transport studies and engineering curricula to increase the content and examples of transport modelling applications and vale add to development. In addition, research, science and funding agencies should also provide more opportunities for increased research funding with a particular bias towards promoting transport modelling projects.

While numerous studies exist that indicate the low visibility of transport modelling activities, it is encouraging to realise that pockets of excellence in transport modelling exist in South Africa and by extension in developing countries. These initiatives and projects can act as a departure point for increased transport modelling collaboration and partnerships that can yield a critical mass of transport modelling research output and technology packages aimed at tackling transport growth and development contemporary matters. Consequently, the need and requirement to establish a platform for transport modelling exchange and network in South Africa, Southern Africa and by extension developing countries cannot be over-emphasised. This envisaged Forum can act as a platform for greater dissemination and exchange of information revolving around transport and land use

modelling, spatial interaction modelling systems as well as traffic and transport engineering modelling systems. A South Africa and or Southern African Transport Observatory is one way of tackling this matter. This can be tasked with the mandate to develop a critical mass of transport modelling experts and database in South Africa in particular and developing countries in general for use in addressing critical land use, infrastructure, transport and engineering growth and development issues. In addition, scope, feasibility and advisability of developing a post-graduate qualification with specialization in transport modelling as a niche area requires keen investigation. Seeking to craft and roll-out innovative ways of upscaling and replicating transport modelling patents, technology packages, protocols and procedures as well as engaging in pilot and demonstration projects should be based on the need for fostering continued dialogue and discussion in the transportation and allied sectors.

Overall, a good base for articulating transport modelling exists in South Africa although the challenges of sparse resources need to be addressed. Scattered and incompatible databanks and datasets has to be addressed. Information that is available relates to National Association of Automobile Manufacturers of South Africa (NAAMSA) Vehicle sales, The National Traffic Information System (eNATIS) vehicle population, National Transport Master Plan/ State of Logistics Survey (NATMAP/SOL) passenger per kilometre and tonne-kilometre data as well as South African Petroleum Industry Association (SAPIA/EB) fuel sales. However, despite protocol access and permission restriction to accessing such databases, with proper requests the data can be accessed and made available for research and development purposes. However, for transport modelling this data requires transformation into data sets that respond to answering questions on namely: inter-city rail commuter and freight tonnages moved; scrap rates; occupancy; load factors; road-rail share; average age and annual mileage. This is essential in making various calculations and scenarios regarding the transport sector. Once this kind of data has been gathered and analysed it is possible to engage in mathematical modelling regarding detailed vehicle passenger by mode of transport; passenger-annual kilometres; tonnes-kilometres per mode share; fuel consumption as well as total vehicle kilometres covered annually, by area etc. Conclusively therefore,

If you cannot accurately predict the future then you must flexibly be prepared to deal with various possible futures. Edward de Bono, Serious Creativity.

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